

# *Austromusotima*, a New Musotimine Genus (Lepidoptera: Crambidae) Feeding on Old World Climbing Fern, *Lygodium microphyllum* (Schizaeaceae)

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**ABSTRACT** During the search for natural enemies of Old World climbing fern, *Lygodium microphyllum* (Cav.) R. Br. (Schizaeaceae), in Australia and southeastern Asia, *Cataclysta camptozonale* (Hampson) was found to be highly specific to this aggressive vine and was tested as a biological control agent. This musotimine moth species has long been misplaced in a European acenotropine genus; therefore, we propose *Austromusotima*, new genus, to accommodate *Austromusotima camptozonale*, new combination, as the type species. The syntype series of *Oligostima camptozonale* is a mixture of specimens of the former species (*sensu stricto*) and its sibling, *Austromusotima metastictalis* (Hampson), new combination. A lectotype is designated for *A. camptozonale* to stabilize the use of the name. The immature stages of *A. camptozonale* are described and compared with other known musotimine immatures. The immatures of *Eugauria albidenta* (Hampson) and *Cataclysta angulata* Moore are illustrated for the first time. *Austromusotima* is most closely related to *Cataclysta seriopunctalis* Hampson based on adult morphological characters, but immatures of *C. seriopunctalis* are unknown, and therefore, this species is not included in *Austromusotima*. The important, yet incongruent, results between immature and adult characters are discussed in the context of phylogenetic relationships of *Austromusotima* to other taxa.

**KEY WORDS** cataclystiform wing pattern, Australia, Papua New Guinea, Indonesia, *Cataclysta*

FERN-FEEDING LARVAE OF MOTHS have been considered potential biological control agents of invasive weedy ferns because of their high specificity and defoliating ability (Lawton et al. 1988, Gason et al. 2000, Strong and Pemberton 2000). From 1997 to 2002, exploration for biological control agents of *Lygodium microphyllum* (Cav.) R. Br. (Schizaeaceae), the Old World climbing fern, was conducted in Australia and southeastern Asia by the Agriculture Research Service (ARS) Australian Biological Control Laboratory (ABCL) in Brisbane, Queensland (Wood 2000, Wood and García 2002). "*Cataclysta*" *camptozonale*, collected from northern Queensland, was discovered among other crambid moths feeding on *L. microphyllum* and was tested for biological control purposes in Australia and Florida (Goolsby et al. 2003). However, taxonomic and phylogenetic problems of this species and

its relatives emerged during a preliminary morphological study.

The current placement of *C. camptozonale* and related species is questionable because assignment in the past has been based only on external adult morphology. These species have been described in various acenotropine taxa with geographical distributions confined to Eurasia (Lange 1956, Yoshiyasu 1980, 1985, Speidel 1984). Their generic placement in acenotropine genera (Table 1), *Oligostigma* Guenée by Hampson (1897), *Nymphula* Schrank by Klima (1937), and most recently, *Cataclysta* Hübner by Shaffer et al. (1996), is because of the striking resemblance in the cataclystiform wing pattern as defined by Munroe (1991) (Fig. 1). The cataclystiform wing pattern is characterized by the presence of marginal and submarginal lines parallel to the termen of the forewing, a postmedial line parallel to the termen from the costal margin to CuA<sub>2</sub>, bending inward between CuA<sub>2</sub> and 1A, then immediately bending downwards to the inner margin, and a series of submarginal black dots along the termen of the hindwing. It occurs in various crambid subfamilies, such as Musotiminae, Nymphulinae, Crambinae, Glaphyriinae, Pyraustinae, Schoenobiinae, and Scoparinae (see Munroe 1972, 1991; Speidel 1984; Yoshiyasu 1985; Scoble 1992; Shaffer et al. 1996; Yen 1997; Solis and Adamski 1998; Fig. 39, Munroe and Solis 1999; Speidel and Mey 1999). This wing pattern,

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Table 1. Generic placement of the *C. angulata* species group (Yen 1997, undescribed genus, Speidel and Mey 1999)

Species	Original genus	Klima (1937)	Shaffer et al. (1996)
<i>camptozonale</i> Hampson	<i>Oligostigma</i>	<i>Oligostigma</i>	<i>Cataclysta</i>
<i>metastictalis</i> Hampson	<i>Nymphula</i>	<i>Nymphula</i>	<i>Cataclysta</i>
<i>angulata</i> Moore	<i>Cataclysta</i>	<i>Cataclysta</i>	"
<i>seriopunctalis</i> Hampson	<i>Nymphula</i>	<i>Nymphula</i>	"
<i>polystictalis</i> Hampson	<i>Nymphula</i>	<i>Nymphula</i>	"
<i>marginipunctata</i> Turner	<i>Cataclysta</i>	"	<i>Cataclysta</i>
<i>pleonaxalis</i> Hampson	<i>Nymphula</i>	<i>Nymphula</i>	"

" Species not included.

in addition to uniform genitalic structures in Acentropinae, led to the erroneous placement of genera and species.

*Cataclysta camptozonale* was described in Acentropinae, a subfamily known for its true aquatic immature stages. (Note: ICZN Opinion 2021 did not give Nymphulinae Duponchel precedence over Acentropinae Stephens; Solis 1999, International Commission of Zoological Nomenclature 2003). *Cataclysta camptozonale* is not an acentropine because the immature stages do not exhibit any of the synapomorphic characters of aquatic Acentropinae discovered by Speidel (1981, 1984) and Passoa (1988). In contrast, information about musotimine immature stages has been scanty and fragmented. Since the taxon was created by Meyrick (1884) (as Musotimidae), only the immature morphology of *Musotima drypterisivora* Yoshiyasu (Nakamura 1977) had been documented. It is only in recent decades that information about immatures concerning *Neomusotima* Yoshiyasu, several undescribed taxa (Solis et al. 2004a, b), and the species discussed in this have been documented. In this study we conduct a comparative morphological study of known musotimine immatures (Table 2) to corroborate that the new genus is necessary and valid.

Also, we discovered that *Oligostigma camptozonale* syntypes in The Natural History Museum, London, represent two different species—one being a polymorphic species known as *Catalysta metastictalis* (Shaffer et al. 1996) (Fig. 1, A, B, and E). Therefore, we clarify the relationship between *C. camptozonale* and *C. metastictalis* to stabilize use of the name for the species that has been bred in the laboratory and tested for biological control purposes. We compared the valid genera and involved taxa of Musotiminae (Table 2) and failed to find a described genus for the *C. camptozonale* species group; thus, we propose *Austromusotima*, new genus, for these two species.

Materials and Methods

**Biological Exploration Methods.** Search areas were selected using climate matching, habitat diversity, herbarium locality data, and knowledgeable specialists. Many localities in Australia were visited between September 1997 and March 2002. At each site, the survey was documented with a unique ABCL collection number, and the following data were collected: date, time

spent searching, site coordinates, temperature, plant growth characteristics, and herbivore species. Most locations were visited several times to account for seasonal effects on herbivore biodiversity. If possible, other *Lygodium* Sw. species were surveyed for herbivores. Methods for collection included hand searches, sweeping, beating of foliage, and dissection of underground plant parts (Goolsby et al. 2003).

**Morphological Study Methods.** In addition to fresh material collected in Australia, specimens were studied from the following collections, whose acronyms are used throughout the text: The Natural History Museum, London, UK (BMNH); National Museum of Natural History, Smithsonian Institution, WA, DC (USNM); and Zoologische Staatssammlung, München, Germany (ZSM). Preserved immature specimens were discovered in the BMNH and USNM collections and used for comparative study.

Morphological study methods mainly follow the protocols of Clarke (1941), Holloway et al. (1987), and Landry (1995). Measurements were made with an ocular micrometer. Terminology mainly follows Hinton (1946), Klotz (1970), Maes (1985, 1995, 1997), Yoshiyasu (1985), Phillips and Solis (1996), and Solis and Maes (2002). Type species, and other species if available, of described genera currently placed in the Musotiminae, including several unpublished genera by Solis et al. (2004a, b) and Yen (2003), were dissected, studied, and compared with determine the identity and/or placement of the taxa studied. In addition, the following references were used for comparative morphology: Lange (1956), Nakamura (1977), Munroe (1968, 1972, 1991), Yoshiyasu (1985), and Phillips and Solis (1996). The genitalia photographs were enhanced with Adobe Photoshop.

Results

***Austromusotima* Yen and Solis, new genus**  
(Figs. 1, C–J; 2, C, D, G, and H; 3, 4; 5; 6A; 7, A and B; and 8, A–C)

**Diagnosis.** Crambid moths with wingspan ≈12–18 mm. Male head with first labial palpal segment geniculate anteriorly (Fig. 2C). Maxillary palpus with developed scale tufts near apex. Postmedial line of male forewing curved inwardly and interrupted near hind angle of cell, but postmedial line of female continuous and extending to inner margin; medial and antemedial lines clearly defined; hindwing with a series of black dots along outer margin, dots smaller at incision between Rs and M<sub>1</sub>. Male genitalia distinguishable from other genera by specialized uncus with an articulated posterior hook, dorsal flagelliform setae, and apical comblike setae; tegumen complex a secondarily derived rooflike structure covering above dorsum of tegumen; juxta bilobed at apex, not acute as in other genera; juxta linked to base of vinculum, extending anteriorly and forming an asymmetrical bifurcate sclerite; paired hooklike structure arising from valval base; aedeagus with developed cornuti. Female genitalia





Fig. 1. Adults. (A) Male lectotype of *O. camptozonale* Hampson, Cedar Bay, Australia. (B) Female paralectotype of *O. camptozonale* Hampson, Cedar Bay, Australia. (C) Laboratory-bred male of *A. camptozonale* from Queensland, Australia. (D) Laboratory-bred female of *A. camptozonale* from Queensland, Australia. (E) Male of *A. metastictalis*, also syntype of *O. camptozonale* Hampson, Fergusson Island, Papua New Guinea. (F) Laboratory-bred darker form of female *A. camptozonale*. (G) Male of *A. metastictalis*, St. Aignan Island, Papua New Guinea. (H) Female of *A. metastictalis*, St. Aignan Island, Papua New Guinea. (I) Male of *A. metastictalis*, Hydrographer Island, Papua New Guinea. (J) Female holotype of *A. metastictalis* Hampson, Goodenough Island, Papua New Guinea.

Table 2. Comparison of adult and immature morphology, host plant, and geographical distribution among musotinine genera

Taxon <sup>a</sup>	Labial palpus of male	Cataclyatiform wing pattern	Posterior part of uncus	Apex of Uncus	Extension of gnathal base	Valval process	Cornuti	Pupal spiracle	Feeding behavior	Host plant	Geographical distribution <sup>a</sup>
<i>Austromosotima</i>	Geniculate	Present	Articulated	Bilobed	Dorsal	Basal, upcurved	Present	Conical	External feeder	<i>Lygodium</i>	IA
" <i>Nymphula</i> " <i>seriopunctalis</i>	Upcurved	Present	Simple	Bilobed	Dorsal	Basal, upcurved	Present	—	—	—	IA
" <i>Nymphula</i> " <i>polystictalis</i>	Upcurved	Present	Simple	Trilobed	Ventral	Basal, upcurved	Absent	—	—	—	IA
" <i>Cataclysta</i> " <i>marginipunctata</i>	Upcurved	Present	Simple	Trilobed	Ventral	Basal, transverse	Absent	—	—	—	IA
<i>Engouria</i>	Upcurved	Present	Simple	Single	Ventral	Distal, transverse	Absent	Plain	External feeder	<i>Nephrolepis</i>	O+IA
" <i>Cataclysta</i> " <i>angulata</i>	Upcurved	Present	Simple	Single	Ventral	Medial, transverse	Absent	Plain	Leaf miner	<i>Nephrolepis</i>	O+IA
" <i>Nymphula</i> " <i>pleonaxalis</i>	Upcurved	Absent	Simple	Single	Ventral	Basal, transverse	Absent	—	—	—	IA
<i>Drosophantis</i>	Upcurved	—	Simple	Single	Ventral	Absent	Absent	Conical	External feeder	Moss	O+IA
<i>Cymoriza</i> <sup>b</sup>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	—	External feeder	<i>Blechnum</i>	P+O+NT
<i>Neomosotima</i>	Upcurved	Absent	Simple	Single	Ventral	Medial, transverse	Absent	Conical	External feeder	<i>Lygodium</i>	O+IA
<i>Lygomusotima</i> <sup>c</sup>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	Conical	External feeder	<i>Lygodium</i>	O+IA
<i>Musotima</i>	Upcurved	Absent	Simple	Single	Ventral	Medial, transverse	Absent	Plain	External feeder	<i>Dryopteris</i>	P+O+IA
<i>Ambia</i>	Upcurved	Absent	Simple	Single	Ventral	Medial, short	Absent	—	—	—	P+O+IA
<i>Melanochroa</i>	Upcurved	Absent	Simple	Single	Dorsal	Absent	Present	—	—	—	O
<i>Uthiria</i>	Upcurved	Absent	Simple	Single	Ventral	Medial, transverse	Absent	—	—	—	P+O
<i>Aclopetra</i>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	—	—	—	O+IA
<i>Albusambia</i> <sup>d</sup>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	Plain	Leaf miner	<i>Elaphoglossum</i>	NT
<i>Uddalambia</i>	Upcurved	Absent	Simple	Single	Ventral	Medial, transverse	Absent	Plain	External feeder	<i>Rumohra</i>	N
<i>Neurophyseta</i>	Upcurved	Present	Simple	Single	Ventral	Medial or distal	Absent	Conical	External feeder	Fern	N+NT
<i>Midlambia</i>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	—	—	—	NT
<i>Parthenodes</i>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	—	—	—	NT
<i>Cilaus</i>	Upcurved	Absent	Simple	Single	Ventral	Absent	Absent	—	—	—	E
<i>Panotina</i>	Porrect	Absent	Simple	Single	Ventral	Medial, transverse	Absent	—	—	—	E

<sup>a</sup> *Barisoa* Möscher, *Malleria* Munroe, *Otilia* Schaus, *Baeoptila* Turner, and *Elachypteryx* Turner are not included because material is too rare for detailed morphological comparison.  
<sup>b</sup> The monophyly of *Cymoriza* Guenée is questionable because its type species is from Brazil, but most species placed in this genus are Palaearctic or Oriental. The information provided in this table is based on Oriental species.  
<sup>c</sup> *Lygomusotima* is to be described in Solis et al. (2004b).  
<sup>d</sup> *Albusambia* is to be described in Solis et al. (2004a).  
<sup>e</sup> Abbreviations of geographical regions: P, Palaearctic; O, Oriental; IA, Indo-Australian; E, Ethiopian; N, Nearctic; NT, Neotropical.



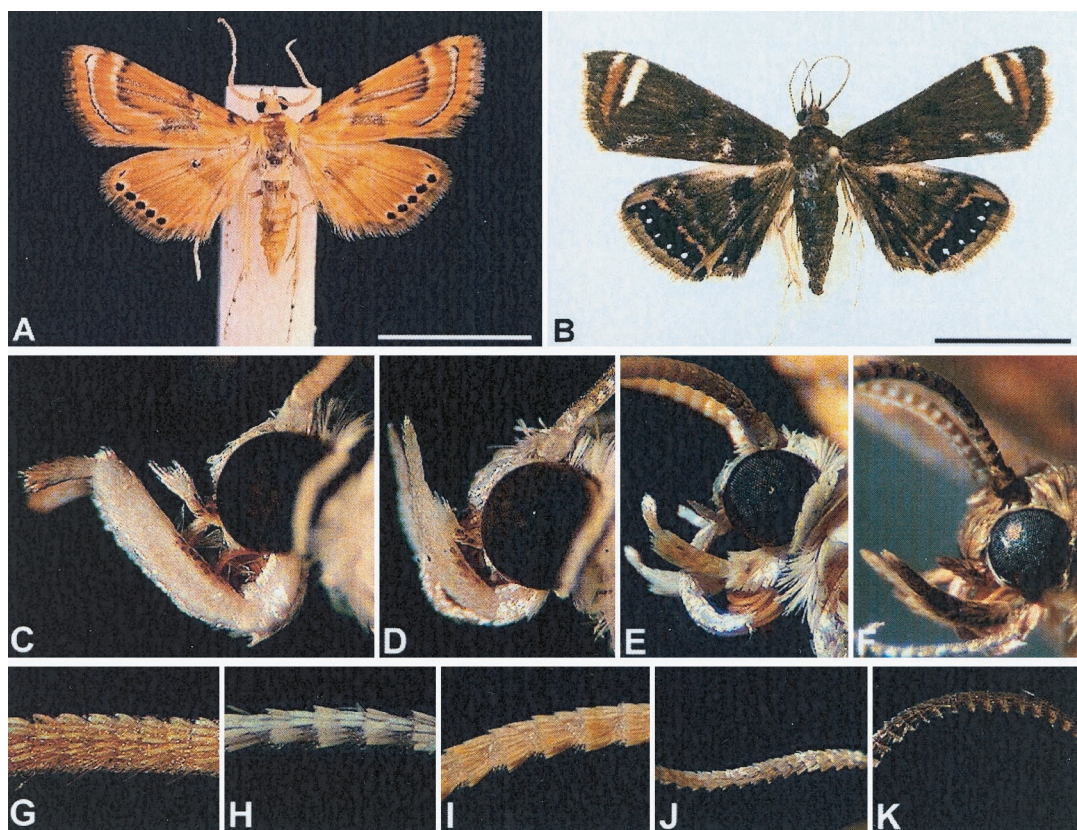


Fig. 2. (A and B) Adults. (A) *C. angulata*, Taiwan. (B) *E. albidentata*, Taiwan. (C-F) Lateral view of adult heads. (C) *A. camptozonale*, male. (D) *A. camptozonale*, female. (E) *C. angulata*. (F) *E. albidentata*. (G-K) Antennae. (G) Male of *A. camptozonale*. (H) Female of *A. camptozonale*. (I) Male of *C. angulata*. (J) Female of *C. angulata*. (K) Male of *E. albidentata*.

characterized by a short ductus bursae and corpus bursae, and paired grooves at ventrolateral sides of seventh sternite. Wing pattern easily distinguishable from *C. angulata* Moore, *C. marginipunctata* Turner, and *Nymphula pleonaxalis* Hampson by white ground color, developed subbasal and postmedial lines, and marginal black dots interrupted by incision of termen of hindwing, and from *N. seriopunctalis* Hampson and *N. polystictalis* Hampson by a more developed wing pattern system other than the marginal and submarginal lines.

#### Description: Adult

**Head** (Fig. 2, C and D). Frontoclypeus covered with smooth scales; vertex not elevated. Labial palpus three-segmented, upcurved and acute in female, but terminal segment in male stout and decumbent, basal segments thickly scaled. Maxillary palpus long, triangularly dilated at apex. Proboscis longer than labial palpus, scaled basally. Antennal flagellomeres prismatic, laterally compressed, thicker in male.

**Thorax.** Legs long, slender; male mid- and hindtibia without any specialized tufts of scales; mid- and hindcoxa bearing short hair tufts; male hindleg with inner spur developed.

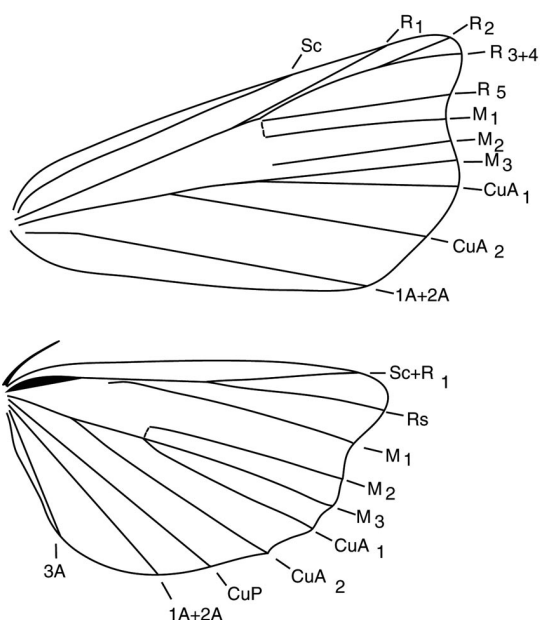


Fig. 3. Forewing and hindwing venation of *Austromusotima*.

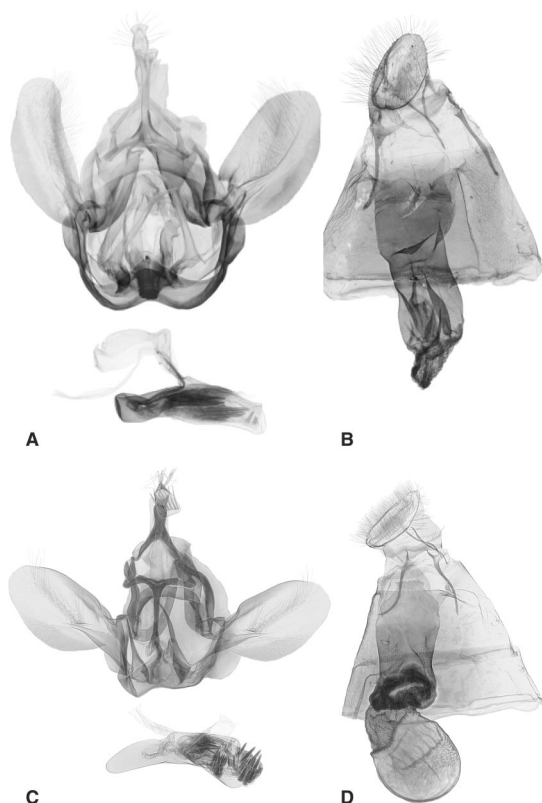


Fig. 4. Dorsoventral view of *Austromusotima* genitalia. (A) Male of *A. camptozonale*, including lateral view of aedeagus. (B) Female of *A. camptozonale*. (C) Male of *A. metastictalis*, including lateral view of aedeagus. (D) Female of *A. metastictalis*.

**Forewing** (Figs. 1, C–J, and 3). Costa straight; apex acute; termen slightly incised or crenulate between  $R_{3+4}$ ,  $R_5$ , and  $M_2$ . Vein  $R_1$  from anterior margin of discal cell,  $R_2$ ,  $R_{3+4}$ , and  $R_5$  close at base;  $M_1$  straight;  $M_2$  to  $CuA_1$  more or less approximate at base; 3A weak. Discocellulars erect. Ground components white, paler in male and more ochreous in female. Forewing with distinct subbasal, antemedial, postmedial, submarginal and marginal lines plus a medial patch on cell. Retinaculum a short set of hooked setae located basally on Cu.

**Hindwing** (Figs. 1, C–J, and 3). Costa almost straight; apex rounded; termen slightly sinuous to tornus. Vein  $Sc + R_1$  anastomosing with  $R_s$  for short distance;  $M_1$  straight;  $M_2$  to  $CuA_1$  as in forewing;  $CuA_2$ ,  $1A + 2A$ , and 3A complete. Antemedial, postmedial, submarginal, and marginal lines plus a series of black dots along termen. Female frenulum two setae, male one seta.

**Abdomen.** Tympanal cases (bulla tympani, caisses tympaniques) enlarged, tympanic frame (fornix tympani, cadre tympanique) highly sclerotized, processes tympani (saillies tympaniques) absent, ramus tympani absent.

**Male Genitalia** (Figs. 4, A and C, and 5, A and B). Tegumen broad, anterior margin with U-shaped incision, with middorsal portion having distinct transverse ridge, and a helmetlike structure derived from conjunction between tegumen base and dorsal margin of vinculum covering tegumen dorsally. Fenestrulae developed, polygonal, separated into two lateral portions at uncus base. Vinculum as long as tegumen, connected with tegumen by a broad sclerotized plate. Saccus moderate in length, curved posteriorly. Uncus long, as long as height of tegumen, slender, with several specialized structures; articulated at one-thirds to apex, apical part broadened in dorsoventral view, a series of thick setae arranged along margin of apex, dorsum of apical part bearing a series of long and twisted setae, basal part slender in lateral view, attenuate toward base, setose posterodorsally and posteroventrally. Gnathos (pseudognathos *sensu* Maes 1997, Solis and Maes 2002) long and narrow, with apical portion extending downwards, with bilobed modification and dorsal teeth; arms prominent, approximately one-third height of tegumen. Transtilla present, bandlike, without lateral lobes. Valva broad; costa and sacculus more thickly sclerotized; inner surface with setal zone which contains dense and short setae; basal part bearing a sharp process. Phallus short and stout; bulbus ejaculatorius  $\approx$  one-half length of phallus; suprazonal sheath long; coecum penis stout,  $\approx$  one-half length of phallus; vesica with a series of thick cornuti. Juxta asymmetrical, deeply bifurcated, derived from base of vinculum, extending anteriorly and then bending posterodorsally. Eighth sternite without modification.

**Female Genitalia** (Fig. 4, B and D). Ostium bursae broad. Lamella postvaginalis present as a pair of auriculate sclerites. Ductus bursae short, sclerotized and smooth, without prominent striae. Corpus bursae short and stout, membranous or weakly sclerotized, not exceeding anterior margin of sixth abdominal segment, without a compact group of signa, appendix bursae absent. Spermatheca without lagena. Papilla

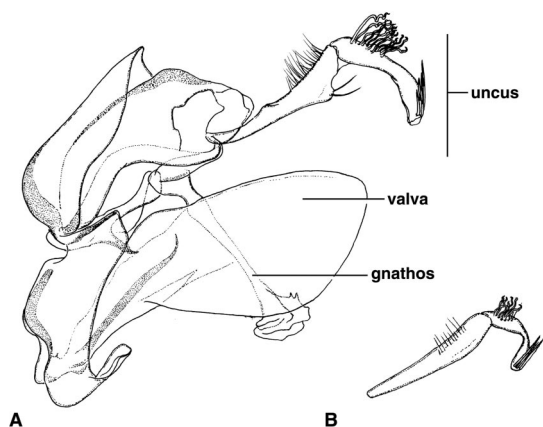


Fig. 5. Lateral view of *Austromusotima* male genitalia. (A) *A. metastictalis*, Fergusson Island. (B) Uncus, *A. camptozonale*, northern Queensland.



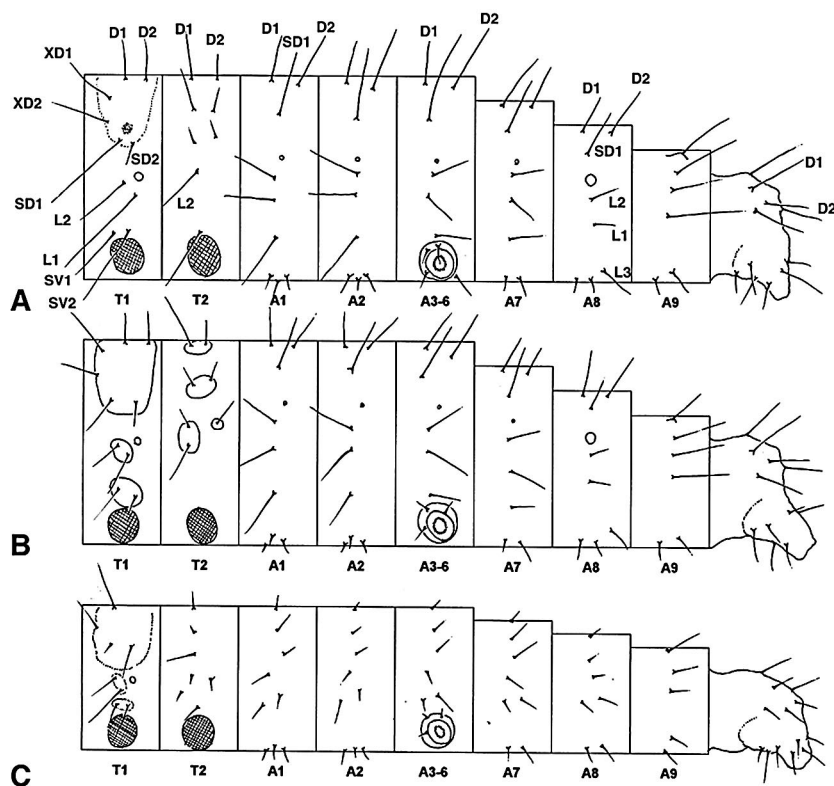


Fig. 6. Larval trunk chaetotaxy. (A) *A. camptozonale*. (B) *E. albidentata*. (C) *C. angulata*.

analis broad and short, with setae on lateral to dorsal surfaces. Apophysis posterioris slender, approximately one-half of seventh sternite; apophysis anterioris slender, approximately two-thirds of seventh sternite. Seventh sternite slightly shorter than tergum.

**Larva** (Figs. 6A and 7, A and B). Head hypognathous, epicranial suture very short; height of frontoclypeus 2.5 times width; six stemmata, C1 and C2 approximate, C3 and C4 approximate, C5 antero-ventrad to C6; S2 as long as S1, SS3 longer than SS2, MG1 short, F1 present near middle of frons, AF1 and AF2 on adfrontal area invisible, La and Aa absent, P2 shorter than P1; labrum with three short setae on each side externally and no seta on each side internally; mandible with one row of serrations. T1–3 and A1–10 integument smooth, segments without chalazae or pinacula. Prothoracic shield weakly sclerotized, D1 and D2 nearly equal in length, XD1, XD2, SD1 and SD2 located on shield, XD1 slightly shorter than XD2, SD1 four times as long as SD2; L setae bisetose, anterior to spiracle; SV setae bisetose. T2–T3 with D setae bisetose; SD setae bisetose; L setae trisetose, L2 much longer than L1 and L3; SV1 present, as long as L2; V seta short. A1–A2 with D setae bisetose; SD group unisetose, SD1 as long as L2 of T2–3; L group bisetose, L2 as long as L1; SV group bisetose, approximately equal in length; V1 present, as long as SV setae. Setal map of A3–6 in general similar to A1–2, SV group trisetose at base of prolegs. A9 with D1 on a large

conical weakly sclerotized chalaza, SD group unisetose; L group unisetose. Anal shield on A10 with prominent D and SD chalazae and D2, SD1 and SD2 at outer margin of anal shield. Prolegs with crochets biordinal in a complete circle.

**Pupa** (Fig. 8, A–C). Ventral view: Frontoclypeus of head slightly protruded; labrum narrow; labial palpus and maxillary palpus absent; proboscis extending to middle of A4; forefemur visible, prothoracic legs (foreleg) three-fourths length of forewing, reaching to middle of A3; mesothoracic leg (midleg) extending beyond hind margin of A4, slightly longer than antennal sheath; hindtarsus not visible; abdominal segments five and six with vestigial prolegs; abdominal segments 8–10 with anterior genital orifice; anus posterior with lateral conical depressions. Dorsal view: prothorax smooth, with two short dorsolateral hornlike structures; mesothorax without seta; spiracles on abdominal segments located on developed conical protuberances; surface of abdominal tergites and wing sheath smooth; a paired lateral cornate protuberance present along margin of abdominal segment 9; cremaster somewhat flattened dorsoventrally with a truncate apex and three pairs of curved setae; a paired, emarginate process on either side of anus densely setose.

**Type Species.** *Oligostigma camptozonale* Hampson.

**Diversity.** Two species are included, *camptozonale* and *metastictalis*.

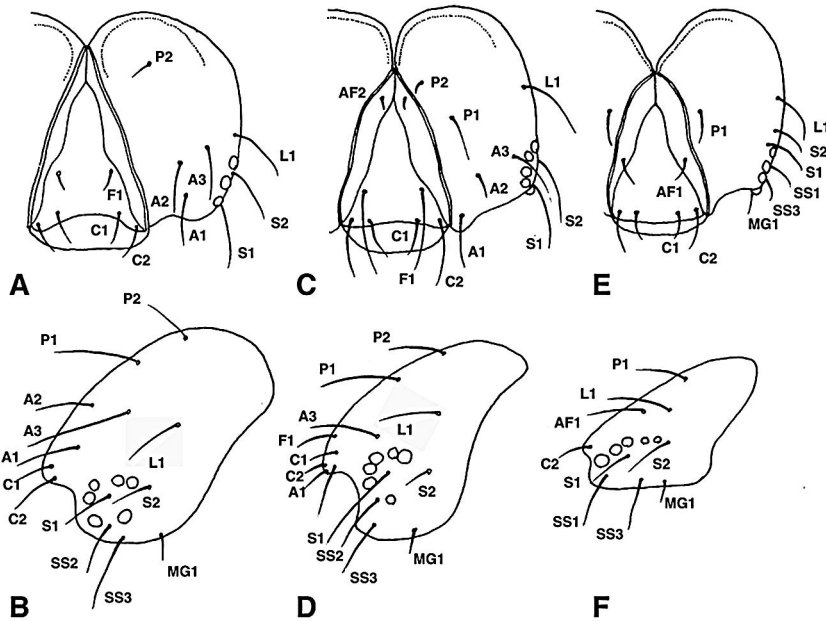


Fig. 7. Frontal and lateral view of larval cranial chaetotaxy. (A and B) *A. camptozonale*. (C and D) *E. albidentata*; (E and F) *C. angulata* (lacks P2 and SS2 setae).

**Distribution** (Fig. 9). The present known distribution of *Austromusotima* is restricted to Australia (Queensland), Papua New Guinea and its associated islands, and Indonesia (Irian Jaya and Moluccas).

**Etymology.** The new generic name refers to its south hemispheric distribution, and its gender is feminine.

*Austromusotima camptozonale* (Hampson),  
new combination

(Figs. 1, A–D and F; 2, C, D, G, and H; 4, A and B; 5B; 6A; 7, A and B; and 8, A–C)

*Oligostigma camptozonale* Hampson, 1897: 169–170 (in part); Klima, 1937: 118; Speidel and Mey, 1999: 138.

*Cataclysta camptozonale*: Shaffer et al. 1996: 185.

**Redescription: Adult**

**Head** (Figs. 1, A–D and F; and 2, C, D, G, and H). Frons, vertex, antenna white ventrally, brown dorsally. Labial palpus three-segmented, first and third segments white; second segment white with some brown scales dorsally, 2.5 times longer than third segment in female, 4 times longer in male; female third segment acute and upturned, male third segment decumbent. Maxillary palpus four-segmented, white ventrally, brown dorsally; fourth segment slightly longer and broader than other segments, with uneven hair tuft.

**Thorax.** Dorsally white with some brown-tipped scales posteriorly. Patagium white, Tegula white with some brown-tipped scales posteriorly. Legs white,

foreleg and midleg with a brown spot at femur/tibia junction, female foreleg with femur and tibia brown medially; tarsal segments brown proximally; midleg with one pair of tibial spurs, hindleg with two pairs of tibial spurs.

**Forewing** (Fig. 1, A–D and F). Average length = 5.79 mm (range: 5.00–6.50 mm;  $n = 14$ ). Ground color white; margin incised between  $R_5$  and  $M_1$  veins. Sub-basal, medial, and postmedial lines dark brown, area from base of  $M_3$  to  $CuA_2$  dark brown, reniform spot in cell brown, subterminal (submarginal line) line light brown, adterminal line with a few dark brown scales, yellow distally; fringe double with short and longer light brown scales. Underside white with postmedial, subterminal, and adterminal lines, and reniform spot visible, costa yellow.

**Hindwing** (Fig. 1, A–D and F). Ground color white. Margin slightly crenulate, incised between  $M_1$  and  $M_2$ , white; medial and postmedial lines brown; subterminal line light brown; adterminal line with 7–9 prominent black spots proximally, 12 prominent black spots in female, yellow distally; fringe double with short and longer light brown scales. Underside white, subterminal line color and pattern as on upperside of wing, costa yellow. Female frenulum two setae, male one seta.

**Abdomen.** White with brown scales on first, second, and third tergites.

**Male Genitalia** (Figs. 4A and 5B). Uncus elongate, apex square, with eight long setae dorsally, medially with a patch of long setae, each twisted apically. Gnathos open apically with short serrations, arms tapered and folded anterodorsally to join uncus arms and tegumen. Juxta bifurcated, almost as long as vinculum,



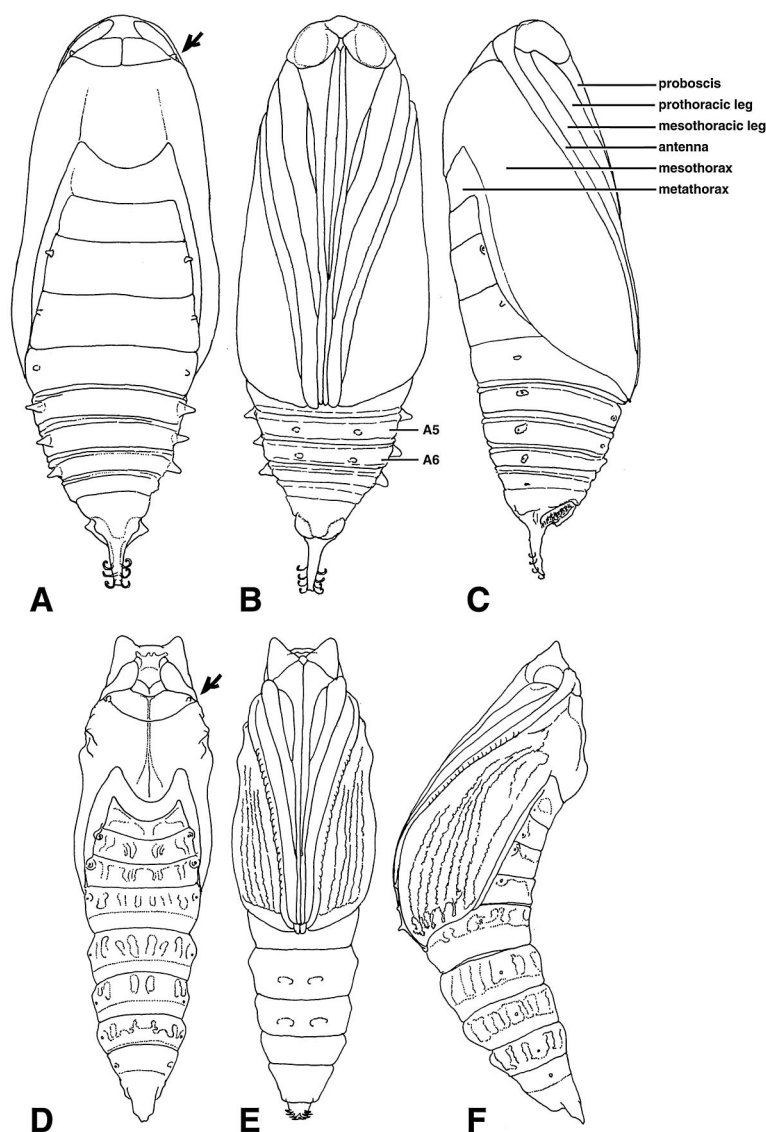


Fig. 8. Pupal morphology. (A) Dorsal view of *A. camptozonale*; arrow indicates hornlike structures on prothorax. (B) Ventral view of *A. camptozonale*. (C) Lateral view of *A. camptozonale*. (D) Dorsal view of *E. albidentata*; arrow indicates hornlike structures on prothorax. (E) Ventral view of *E. albidentata*. (F) Lateral view of *E. albidentata*.

basally attached to pocketlike saccus. Transtilla complete and broad, lightly sclerotized ventromedially, membranous dorsally. Valva with apical margin rounded, medially with long setae, invaginated basally, with a more basal, sclerotized pronglike structure longer than tegumen. Sacculus indented medially. Vinculum as long as tegumen. Tegumen broad dorsally. Aedeagus with more than 10 thick cornuti longer than thickness of phallus.

**Female Genitalia** (Fig. 4B). Bursa copulatrix of even diameter tapering slightly anteriorly, posteriorly membranous, medially lightly sclerotized, anteriorly membranous with short spines; ductus bursae and corpus bursae not differentiated. Appendix bursae absent. Ductus seminalis dorsoposteriorly from apical

membranous area. Ostium bursae membranous. Lamella antevaginalis folded and a sclerotized plate dorsally with a jagged posterior margin. Anterior apophyses and posterior apophyses of equal length, posterior apophyses broader than anterior apophyses. Papillae anales dorsoventrally flattened, twice as long as wide.

**Egg.** Translucent pale yellow, in clusters.

**Larva** (Figs. 6A and 7, A and B). Last instar average length 10.25 mm (range: 9.62–11.70 mm;  $n = 32$ ), head capsule average width 1.05 mm (range: 0.91–1.17;  $n = 32$ ), cylindrical, light green.

**Pupa** (Fig. 7, A–C). Dark brown throughout. Length: 6.39 (range: 5.59–7.15 mm;  $n = 20$ ).

**Types.** LECTOTYPE (designated here to fix the concept of the name and to ensure universal and

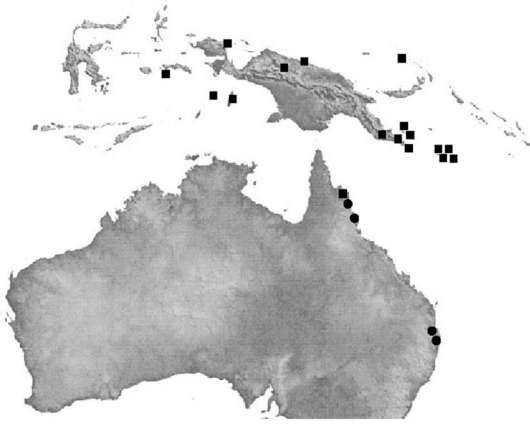


Fig. 9. Distribution map of *Austromusotima*. ●, *A. camptozonale*; ■, *A. metastictalis*.

consistent interpretation of the same.): ♂, (Australia, Queensland), "Geraldton, /near Cairns / (Meek)", "Oligostigma/camptozonale/type ♂. Hmpsn." (abdomen enclosed in a capsule pinned with the specimen), Meek (BMNH). **PARALECTOTYPES:** 1 ♀, 2 ♂, (Australia, Queensland), "Cedar Bay, /s. of Cooktown/ (Meek)", "Oligostigma/camptozonale/type ♀ Hmpsn." (abdomen of one enclosed in a capsule pinned with the specimen), Meek (BMNH); 1 ♂ (Australia, Queensland), QLD, Geraldton, "Oligostigma/camptozonale/Hmpsn.", Rothschild Bequest B.M. 1939-1, Meek (BMNH) (see remarks below for the taxonomic identity of the syntypes from Fergusson Island and Ambon).

**Other Material Examined.** 2 ♂, 2 ♀, Australia, Queensland, 32.5 km SE Brisbane, 27°40.01' S 153°16.03' E, 2-11-1999, LEP Pyralidae reared from larva feeding on pinnules of *Lygodium microphyllum*, J. Goolsby (USNM); 3 ♂, 3 ♀, Australia, Queensland, Logan, Carbrook Creek, *Lygodium microphyllum*, reared in Florida, Alachua Co., Gainesville, DPI, FBCL quarantine, 25-IX-01, G. R. Buckingham (USNM); 4 ♂, 4 ♀ (Australia, Queensland), Cedar Bay, south of Cooktown, Meek (BMNH).

**Geographical Distribution** (Fig. 9). Australia (Queensland).

**Biology.** Females generally oviposit on the underside of the fern pinna. Eggs are laid singly or in small clusters of 6–10, mostly on the new growth. There are five larval instars, with 6–10 generations per year in the subtropics. Populations are active year round at very low levels but tend to peak after the rains. Early instar larvae skeletonize *L. microphyllum* leaves, and fourth- and fifth-instar larvae consume entire leaves. They pupate above ground on the plant in a concealed location. The developmental period from egg to adult at 25 °C is ≈25 d. This species seems to be a *Lygodium* specialist; it has been collected only from *L. microphyllum* and *Lygodium reticulatum* Schkuhr.

**Remarks.** Hampson (1897) stated that *O. camptozonale* was described based on "specimens from Amboina, Fergusson Island, Queensland and W. Australia."

Hampson also stated that "The Amboina and Fergusson Island forms have the markings broader and more interrupted than the Australian." We found 17 specimens in the BMNH collection, which are the potential syntypes used by Hampson. Among them, nine specimens from Fergusson Island (1 ♂, 1 ♀, Papua New Guinea, Fergusson Isl[and], XII-[18]95, A.S. Meek [BMNH]; 5 ♂, 2 ♀, same locality, X-[1891], A.S. Meek [BMNH]; 1 ♀, same locality, X-[18]96, A.S. Meek [BMNH]) and one from Ambon Island (1 ♂, [Indonesia], Amboyna [Ambon], February 1892, "Oligostigma/camptozonale/Hmpsn.", W. Doherty [BMNH]) are *A. metastictalis*. Therefore, we exclude these specimens from the paralectotype series of *A. camptozonale*.

Some *A. camptozonale* females from Queensland have a darker ground color (Fig. 1F) that is similar to that of the female of *A. metastictalis*. These individuals can be distinguished from *A. metastictalis* by their smaller size, a narrower white area near the apex of the forewing, and the lack of a ridged and spinulate corpus bursae.

*Austromusotima metastictalis* (Hampson),  
new combination

(Figs. 1, E and G-J; 4, C and D; and 5A)

*Oligostigma camptozonale* Hampson, 1897: 169–170 (in part).

*Nymphula metastictalis* Hampson, 1917: 370; Klima, 1937: 88; Speidel and Mey, 1999:138.

*Cataclysta metastictalis*: Shaffer et al., 1996: 185.

**Redescription: Adult**

**Head** (Fig. 1, E and G-J). Frons, vertex, antenna white, brown dorsally. Labial palpus three-segmented, first and third segments white; second segment white with some brown scales dorsally, 2.5 times longer than third segment in female, four times longer in male; female third segment acute and upturned, male third segment stout and decumbent. Maxillary palpus white ventrally, brown dorsally; fourth segment slightly longer, and broader than other segments, with uneven hair tuft.

**Thorax.** Dorsally white with some brown-tipped scales posteriorly; patagium white, tegula white with some brown-tipped scales posteriorly. Legs white, foreleg and midleg with a brown spot at femur/tibia junction, female foreleg with brown femur and tibia medially; tarsal segments brown proximally; midleg with one pair of tibial spurs, hindleg with two pairs of tibial spurs.

**Forewing** (Fig. 1, E and G-J). Average length = 8.10 mm (range: 7.80–8.40 mm;  $n = 25$ ). Ground color white. In male, marginal line orange or yellow, fringes creamy white, submarginal line grayish brown, extending from  $R_3 + 4 + 5$  to tornus, postmarginal band starting from ending of  $R_2$ , parallel with outer margin, broadened between  $M_3$  to  $CuA_2$ , curved downwards

to inner margin; medial patch present in discal cell, darker than postmedial band; antemedial line separated, starting from costal margin to inner margin, but interrupted from discal cell to base of 2A; subbasal patch only present between costal margin and subcostal vein. Ground color of female brownish yellow or brownish white, wing pattern similar to male, but with linear postmedial line, antemedial line continuous, and discoidal patch formed by a white spot bordered with brown bars.

**Hindwing** (Fig. 1, E and G-J). Similar to that of *A. camptozonale*, but with broader postmedial and antemedial lines in male; ground color of female darker than in *A. camptozonale*.

**Abdomen.** Male abdomen creamy white dorsoventrally, with dark brown or dark gray scales on third and fourth tergites; in female, abdomen brown dorsoventrally, without dorsal darker scales.

**Male Genitalia** (Figs. 4C and 5A). General structure identical with that of *A. camptozonale*. Posteroventral projection of basal part of uncus more developed than in *A. camptozonale*, length of cornuti about thickness of phallus, bulbus ejaculatorius shorter than phallobase.

**Female Genitalia** (Fig. 4D). General structure as in *A. camptozonale*.

Ductus bursae longer than seventh abdominal segment, with anterolateral depressions, covered by minute spinules. Base of corpus bursae twisted, ridged and covered by numerous spinules, main part of corpus bursae globular, slightly wrinkled.

**Immature Stages.** Unknown.

**Holotype.** HOLOTYPE: ♀, (Papua New Guinea), "Goodenough Isl., 2,500–4,000 feet, /March, 1913/A.S. Meek," "218," "Nymphula/metastictalis/type ♀ Hmps., A.S. Meek (BMNH).

**Other Material Examined.** 1♂, Papua New Guinea, Hydrographer Mt., 2500 feet, April–May 1918, Eichhorn Bros, Rothschild Bequest, B.M. 1939–1, Eichhorn (BMNH); 1♂, same locality, I-1918, Eichhorn (BMNH); 2♂, 2♀, same locality, III-1918, Eichhorn (BMNH); 1♂, same locality, IV-1918, Eichhorn (BMNH); 1♂, same locality, II-III-1918, Eichhorn (BMNH); 1♀, same locality, II-1918, Eichhorn (BMNH); 4♂, Papua New Guinea, Milne Bay, XII-18198, A.S. Meek (BMNH); 1♂, Papua New Guinea, Mt. Riu, 2,000 feet, Sudest Isl[and], III-1916, Eichhorn Bros. (BMNH); 1♂, same locality, IV-1916, Eichhorn (BMNH); 1♂, 2♀ Ron J., VII-18197, W. Doherty (BMNH); 1♀, Papua New Guinea, St. Aignan, IX-1897, A.S. Meek (BMNH) [identified as *Oligostigma camptozonale* by Hampson]; 1♂, 1♀, same locality and collector, XI-1897, (BMNH); 1♂, 2♀, same locality and collector, X-1897, (BMNH); 1♂, 1♀, same locality and collector, VIII-1897, (BMNH); 2♂, St. Aignan, (date unknown), A.S. Meek (BMNH); 1♂, Papua New Guinea, Louisiade, (date unknown), A.S. Meek (BMNH); 1♀, Papua New Guinea, Goodenough Isl[and], 2,500–4,000 feet, III-1913, A.S. Meek (BMNH); 1♂, 3♀, same locality, IV-1913, A.S. Meek (BMNH); 1♂, 1♀, same locality, V-1913, A.S. Meek (BMNH); 1♀, Papua New Guinea, Sariba I[land]

(date unknown), A.S. Meek (BMNH); 1♂, Papua New Guinea, Rossel I., II-18198, collector unknown (BMNH); 1♂, Papua New Guinea, New Hannover, IV-1923, A.S. Meek (BMNH); 1♀, Indonesia, Dorey [Doré Bay], VI-97, W. Doherty (BMNH); 2♂, 1♀, Indonesia, Kumusi R., low elev[ation], VII-19107, A.S. Meek (BMNH); 1♀, same locality, V-19107, A.S. Meek (BMNH); 1♀, Mt. Goliath, 5–700 feet, II-1911, A.S. Meek (BMNH); 2♂, 2♀, Humboldt Bay, IX-X-1893, W. Doherty (BMNH); 1♀, Irian Barat, Brazza River, 250 m, 11-XI-1971, G. Konrad (ZSM); 1♂, same locality, 18-XI-1971, G. Konrad (ZSM). Syntypes of *O. camptozonale*: 1♂, 1♀, Papua New Guinea, Fergusson Isl[and], XII-18195, A.S. Meek (BMNH); 5♂, 2♀, same locality, X-1891, A.S. Meek (BMNH); 1♀, same locality, X-18196, A.S. Meek (BMNH); 1♂, Indonesia, Amboyna [Ambon], February 1892, "Oligostigma/ camptozonale/ Hmps., W. Doherty (BMNH).

**Biology.** Adults appear throughout the year, usually peaking after the wet season. The biology is similar to that of *A. camptozonale*.

**Distribution** (Fig. 9). Papua New Guinea, Indonesia, and also possibly in northern Queensland, Australia.

**Remarks.** There are some differences in the wing pattern among the populations from different islands. The males from Fergusson Island have the postmedial and antemedial bands separated on both fore- and hindwings. The males from St. Aignan Island have forewing postmedial and antemedial bands that broadly meet at the inner margin. Males from Hydrographer Island have the antemedial and postmedial bands of the forewing separated but those of the hindwing nearly fused between 1A-2A. Except for material in the BMNH and ZSM collections, we have not seen other specimens so we are not certain if the differences in wing patterns are correlated with geographical distribution, seasonal variation, or diet quality. We also have not found any significant differences in genitalia among populations with different wing patterns. A specimen from Queensland (1♂ [Australia], Queensland, Kurande, n[ear] Cairns, Dodd 1910 [BMNH]) shares a similar wing pattern with the population from Goodenough Island, but is smaller in size. The abdomen of this specimen, however, is missing, so we could not confirm its identity. Further investigation is needed to clarify if *A. camptozonale* and *A. metastictalis* are sympatric in northern Queensland.

Externally, the female of *A. metastictalis* appears similar to *Haritala szentivanyi* Munroe (1968, Fig. 1), a pyraustine also found in Papua New Guinea (Bisiummu). *H. szentivanyi* can be distinguished easily from *A. metastictalis* by its larger size, approximately one-third longer wingspan; lack of postmedial and antemedial lines in hindwing; marginal line represented by dashed lines; discal spot black; long and large corpus bursae, longer than A5; and narrowed ductus bursae with transverse ridges (Munroe 1968, Fig. 6).



## Discussion

**Subfamily Placement of *Austromusotima*.** Although *A. camptozonale* and *A. metastictalis* were placed in Musotiminae by Speidel and Mey (1999), the placement of these taxa was not based on a clearly defined concept of the subfamily. The adult-based monophyly and phylogenetic relationships of Musotiminae to other crambid taxa is still ambiguous (Solis and Maes 2002). The three consensus cladograms of crambid phylogenies (Solis and Maes 2002) supported the monophyly of Musotiminae with the following character states: (1) spinula (of praecinctorium) present; (2) ductus seminalis originating beyond the middle of the ductus bursae; (3) vinculum as long as the tegumen + uncus; (4) median basal area of the valvae simple; (5) labial palpus upturned; and (6) chaetosemata present. These character states, however, cannot be used to distinguish musotimines from other crambid taxa because they are not unique to the subfamily (Solis and Maes 2002).

Minet (1981, 1983, 1985), using *Cilaus* Joannis, a monotypic genus from Reunion Island, suggested that one of the synapomorphies of Musotiminae is the "enlarged tympanal bullae" (Munroe and Solis 1999). However, this tympanic character does not occur in some purported musotimine genera, e.g., *Aelopetra* Meyrick (Yen 1996) and *Eugauria* Snellen (Yen 1997). Yoshiyasu (1985) proposed "the anteriorly extended gnathos" to support the monophyly of Musotiminae. However, interpretations of homology, based on small taxon samples from restricted geographical areas, of the gnathos, the pseudognathos, and the tegumen-ventral plate (t-v plate) by different authors (Yoshiyasu 1985, Maes 1997, Solis and Maes 2002) have made definition and use of these characters more complex. These genitalic characters require analysis across all musotimine taxa. Musotimines hold their antennae parallel to the thorax and abdomen, as Fernández-Yépez et al. (1996) suggested for Pyraloidea. Our field observations do not suggest that antennal positions of resting musotimines (Uno 1992, Yen 1997, Solis et al. 2004) can distinguish musotimines from acenotropines (see Yoshiyasu 1980, Fig. 5E; Speidel and Mey 1999, Fig. 2) and some pyraustines.

Therefore, our focus transferred to immature stages for possibly providing informative characters to place *Austromusotima* within Musotiminae. Our morphological comparison (Table 2) shows that the larval chaetotaxy of *Austromusotima*, *Neomusotima* Yoshiyasu, *Musotima* Meyrick, *Cymoriza* Guenée, and *Eugauria* are similar in the relative positions of D1 and D2 to SD1 (Figs. 6, A and B, and 7, A–D). These genera and *C. angulata* also share a pair of lateral horns on both sides of the prothorax of the pupa (Fig. 8, B and E). In *Austromusotima*, *Neomusotima*, *Drosophantis* Meyrick, and *Neurophyseta* Hampson, the pupal spiracles from A2 to A7 are protruding and conical (Fig. 8, A and B). Therefore, the morphology of immatures provides strong support for placement of the new genus in Musotiminae.

**Monophyly and Relationships of *Austromusotima*.** *Austromusotima* bears several adult characters unique among the compared taxa: the third segment of male labial palpus is geniculate in shape and decumbent, whereas all other taxa, except for *Panotima* Meyrick, bear upcurved labial palpi; it has a sexually dimorphic wing pattern, all other taxa are not sexually dimorphic; the posterior part of the uncus is articulated with a hook; the apex of the uncus is tapered with a transverse row of setae; the tegumen is covered by a helmetlike structure; the inner surface of the valva has a setose transverse zone and an upcurved, long and sharp process arising from the sacculus of the valva, in many taxa, this process either arises from the medial part of the sacculus or extends transversely or parallel to the sacculus.

During our search for a potential sister group, we first investigated taxa that had previously been associated with *Austromusotima*. In addition to acenotropine genera, *Oligostigma* and *Nymphula*, *A. camptozonale* and related species in the last decade were associated with *Cataclysta* sensu Shaffer et al. (1996) and the *C. angulata* species group sensu Yen (1997) and Speidel and Mey (1999). The contents of these two groupings, however, are very different and not monophyletic. Shaffer et al. (1996) placed the following in *Cataclysta*: three acenotropine species (*lamptialis* Walker, *polyrrapha* Turner, *melanolitha* Turner), three musotimine species (*camptozonale*, *metastictalis*, *marginipunctata*), and *psathyrodes* Turner, currently a species of uncertain position. The concept of *Cataclysta* by Shaffer et al. (1996) also included the Neotropical acenotropine *Cryptocosma* Lederer and its junior synonym *Chalcoelopsis* Dyar (see Munroe 1995) and the Oriental musotimine genus *Eugauria*. We exclude the acenotropine taxa and *C. psathyrodes* from the present discussion because they are not relevant to the relationships of *Austromusotima*. *Eugauria* was created in Acentropinae (Snellen 1901, Klima 1937), synonymized with *Cataclysta* by Shaffer et al. (1996), and revived as a valid genus and transferred to Musotiminae by Speidel and Mey (1999).

The concept of the *C. angulata* species group (Table 1) by Yen (1997) and Speidel and Mey (1999) is comprised of seven musotimine species, i.e., *angulata*, *seriopunctalis*, *polystictalis*, *marginipunctata*, *pleonaxalis*, *camptozonale*, and *metastictalis*. All species demonstrate the cataclystiform wing pattern. In Table 2, we compare several features of musotimine taxa, including the two species of *Austromusotima* and the remaining five species of the *C. angulata* species group.

Contrary to previous suggestions, *Austromusotima* is probably not closely related to *Eugauria* or the *C. angulata* species group. Yen (1997) hypothesized that *A. camptozonale* and related species could be related to the Indo-Australian *Eugauria*. However, on comparison of both the immature and adult morphology of *Eugauria albidentata* (Hampson), feeding on *Nephrolepis* Schott, ferns from Taiwan and Malaysia, with those of *A. camptozonale*, we do not consider *A. camptozonale* to be associated with *Eugauria*. *Aus-*

*trismusotima* genitalia are highly modified, and the pupa is not papilionid-form (Fig. 8, C and D); the latter is unique to *Eugauria* and *C. angulata*. It is interesting to note that *Eugauria* and *C. angulata* have similar genitalic structures, identical pupal shape, and the same host plant association, but they have different wing patterns (Fig. 2, A and B) and completely different larval feeding behaviors, which are reflected by their head orientation and chaetotaxy (Table 2; Figs. 6, B and C, and 7, C–F).

Among the compared taxa, *N. seriopunctalis* seems to be the most closely related taxon to *Austromusotima*. They share four additional unique characters, i.e., an uncus with a bilobed apex, a vinculum extending posteriorly, a gnathos folded dorsally, and a deeply bifurcated, asymmetrical juxta. However, we do not intend to include *N. seriopunctalis* in *Austromusotima* or describe a new genus until its immature stages are discovered. The similar adult morphology and different larval stages of *Eugauria* and *C. angulata* do not encourage us to predict immature morphology based on the adult features. Likewise, the systematic position of the remaining species of the *C. angulata* species group, *polystictalis*, *pleonaxalis*, and *marginipunctata*, with similar genitalic structures cannot be inferred because of the lack of information about the immature stages.

Additional data on the following questions are required for a comprehensive phylogenetic analysis, and several authors (including those of this paper) are currently searching for, studying, and describing new musotimines worldwide. Until the immature stages of some genera are discovered, the phylogenetic context for examining these questions remains relatively weak. For example, the pupae of *Austromusotima*, *Neomusotima*, *Drosophantis*, and *Neurophyseta* have protruding spiracles on abdominal segments 2–7. However, none of the latter three genera bear any of the unique genitalic characters of *Austromusotima*. Thus, the question is whether adult and immature characters comprise independent evidence of relationship or generate incongruent relationships. Finally, *Austromusotima* poses several, more general intriguing questions, particularly about biogeographical origin, origin and purpose of sexual dimorphism in wing pattern, an uncommon feature in Pyraloidea, origin and function of the cataclystiform wing pattern, and origin and evolution of complex genitalic structures.

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